Thermal and Vibrational Stability of the LCLS Undulator Support System

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and

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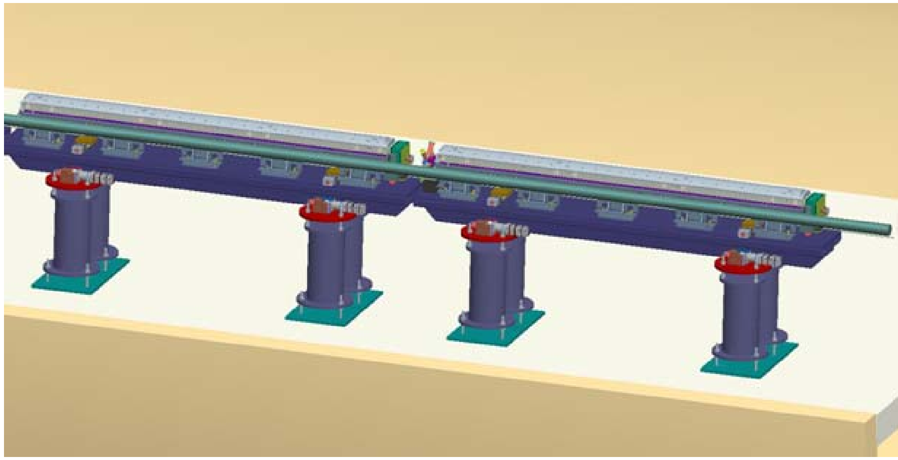
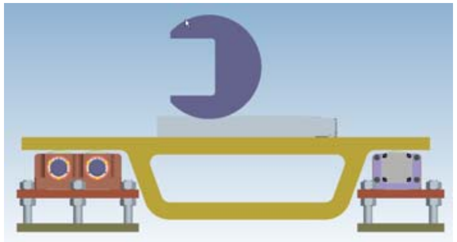
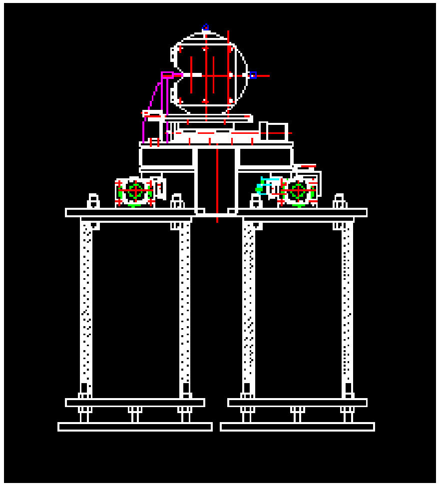
Topics

- **Present Concept of the Fixed Support Stands**
- **Thermal Stability**
- **Vibrational Stability**

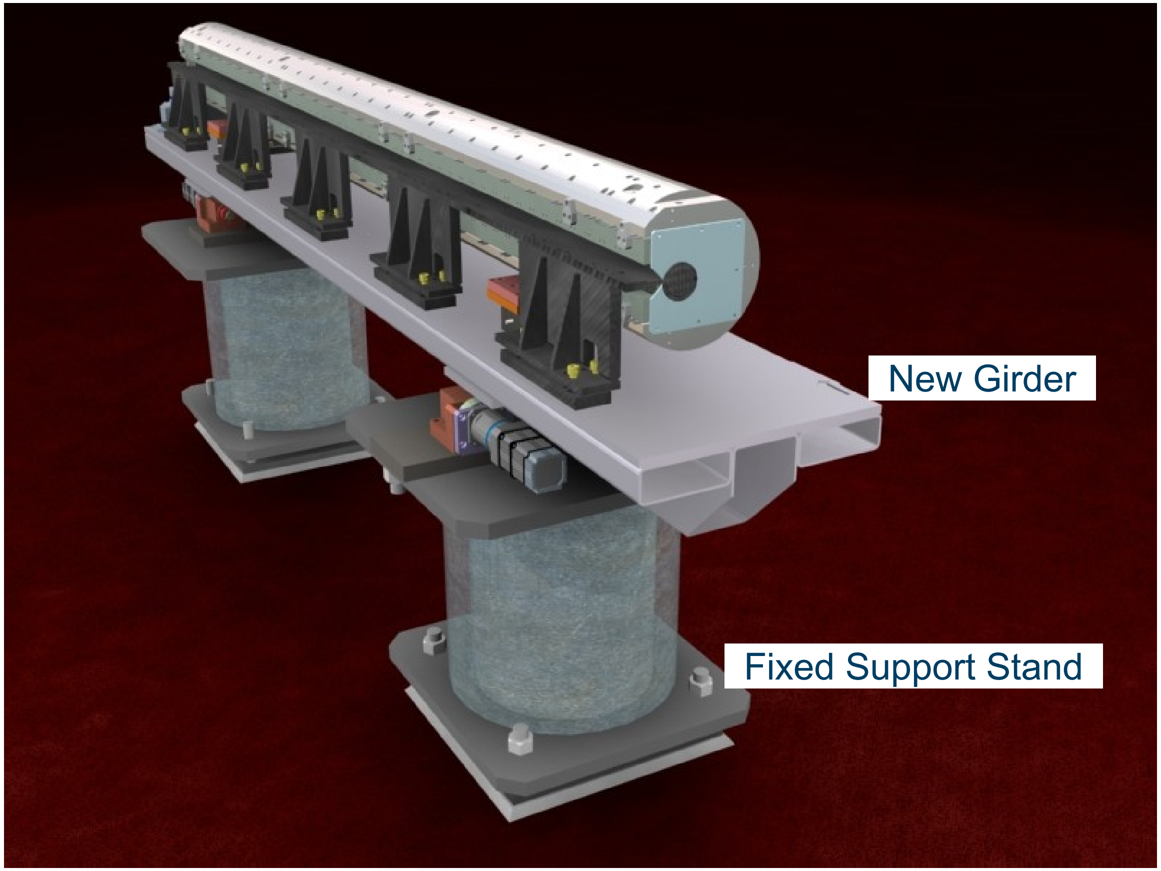


Fixed Support Stands – Previous Version



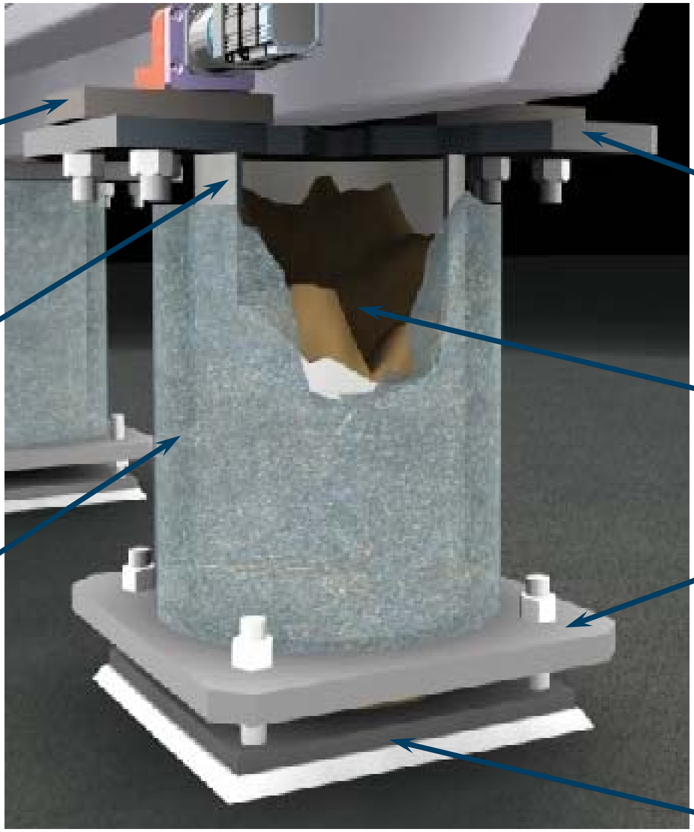


Fixed Support Stands – Assembly



Only two fixed support stands are used for each undulator assembly.

Fixed Support Stands – Main Features



In Progress: (1) An alignment plate to mount each pair of cam movers.
(2) Plate thicknesses, stiffeners and bolt patterns.

Fixed Support Stand – Thermal Analysis

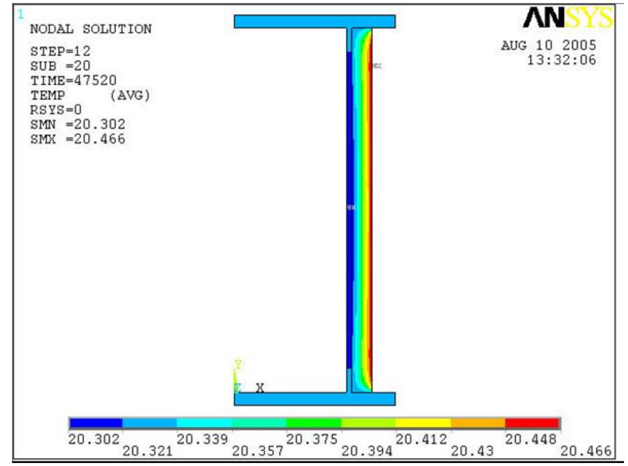
Assumptions:

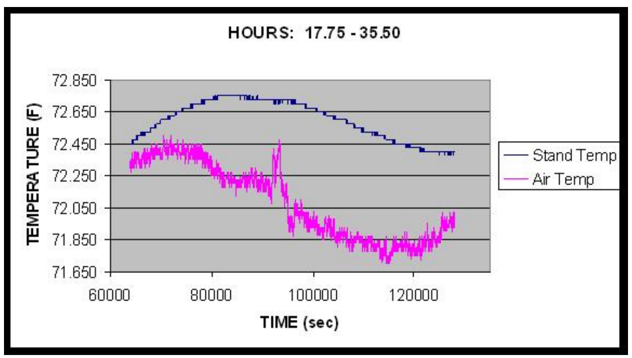
1. The FE analysis is 2-D axisymmetric.
2. Only ΔT with time is modeled.
3. Ambient temperature increases linearly by 0.5 ºC in 12 hours and then decreases linearly by the same amount in the next 12 hours.

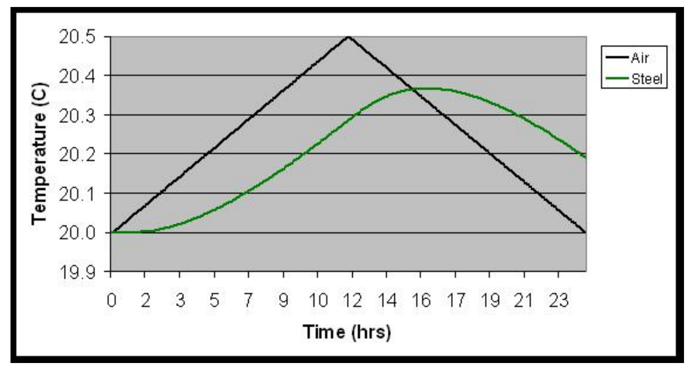
Material Properties

	Density (Kg/mm^3)	Specific heat (J/Kg-ºC)	Conductivity (W/mmK)	Young's Modulus (MPa)	Poisson's ratio	CTE µm/m-ºC
Mineral Wool	1.28E-7	920	0.00004	0.45	0.25	9
Mild Steel	7.8E-6	470	0.052	200	0.25	9.5-12.6
Sand	1.494E-6	1172.3	0.00051	15	0.2	10

Comparison with Experiment

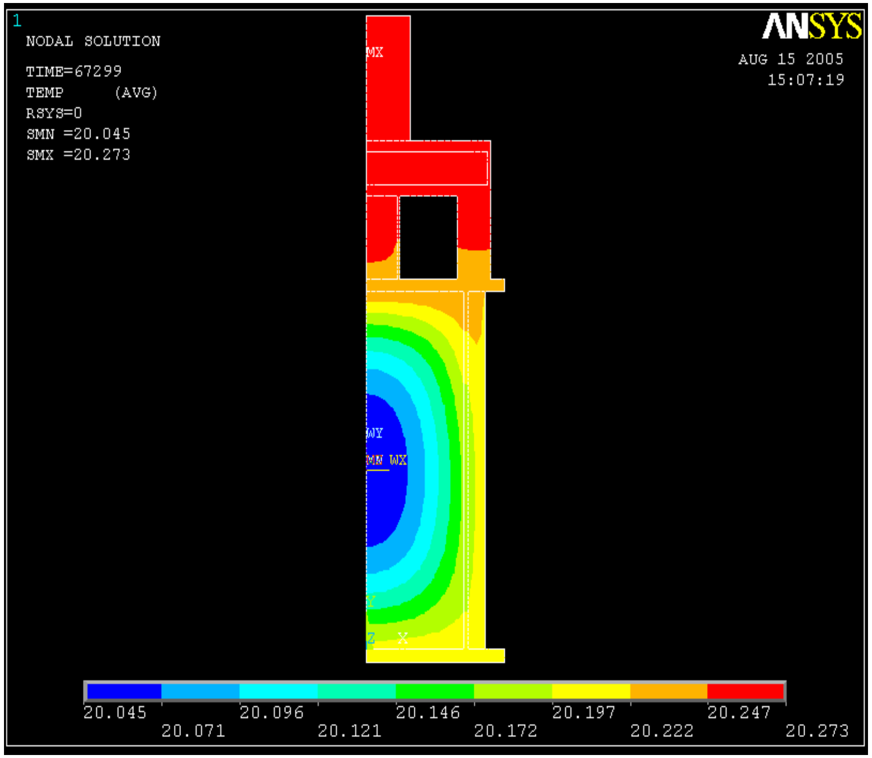




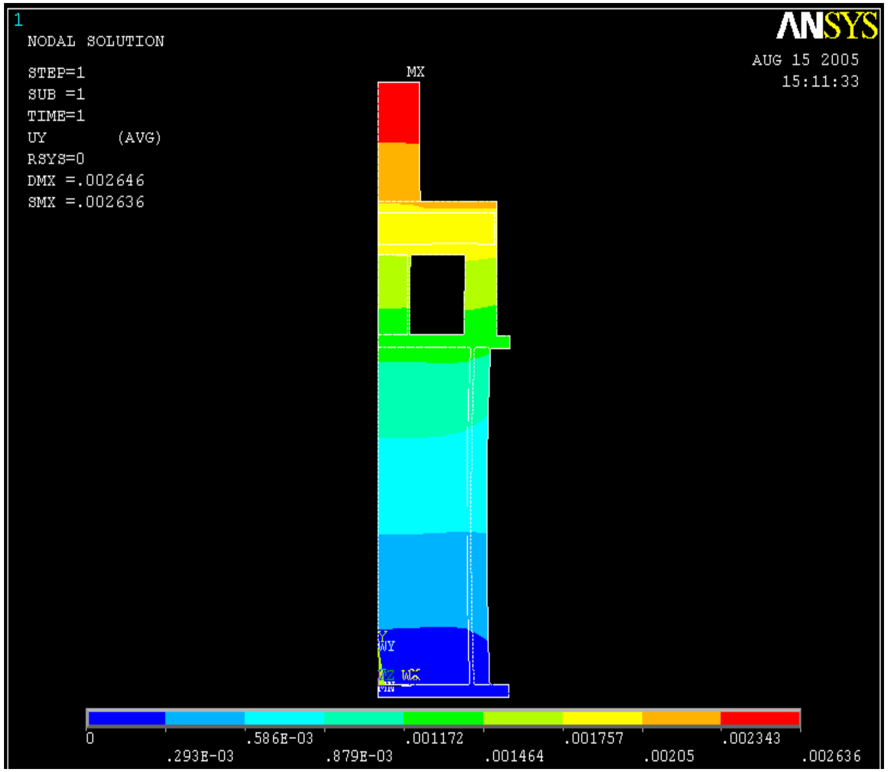


Time = 12 hrs	Experimental	FEA
ΔT air (°C)	0.5	0.5
ΔT steel (°C)	0.33	0.37

Thermal Analysis Results



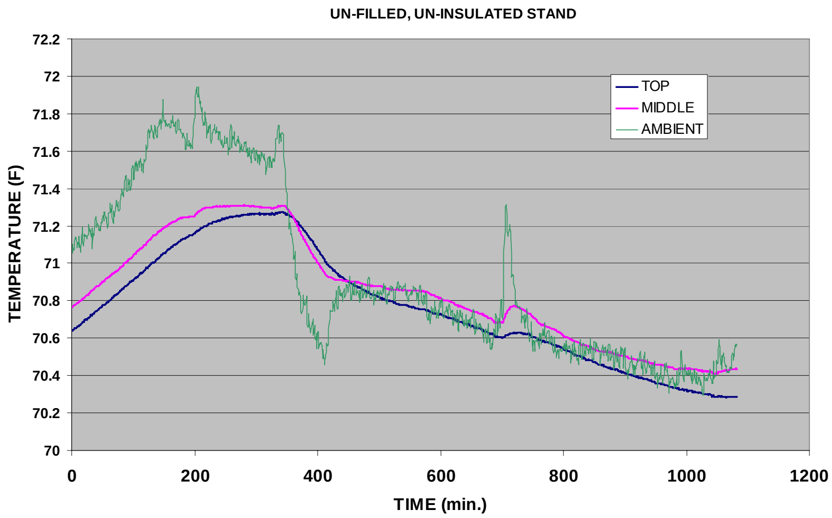
Thermal Contours

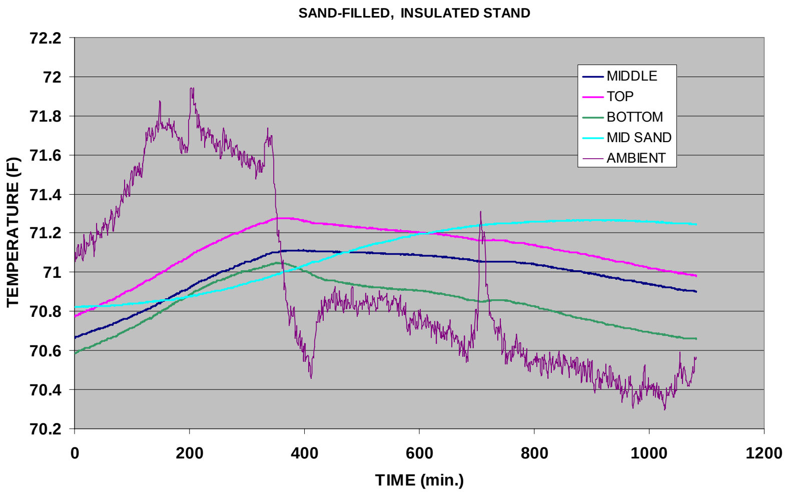


Deformation Contours

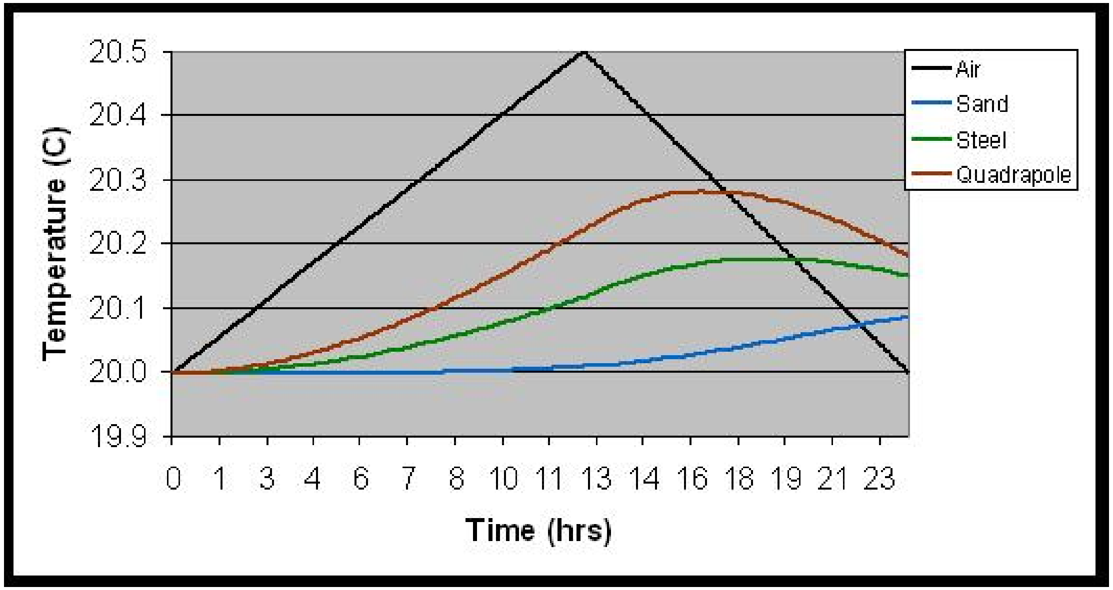
Insulated Sand-filled Support Stand + Sand-filled Girder + Quadrupole

Additional Experimental Data





Thermal Analysis Results



Insulated Sand-filled Support Stand + Sand-filled Girder + Quadrupole

CASE	ΔT (°C) Support Stand	ΔT (°C) Quadrupole	Max. Displacement (μm)
Support Stand + Girder	0.20	0.360	2.8
Support Stand + Sand-filled Girder	0.176	0.272	2.6
Support Stand + Sand-filled and Insulated Girder	0.163	0.234	2.3

The Support stand is insulated and sand-filled in all cases.

Vibrational Stability

- Vibration tolerance for the undulator quadrupoles: 200 nm
  (P. Emma, email, 8/2/2005)
- Vibration Tolerance on LTU quadrupoles: 50 nm
- The tolerance is to be interpreted as rms in 1-100Hz band.

Quadrupole & Solenoid Magnet Vibration Tolerances

Table 1. Vibration sensitivities and rms tolerances (x and y considered equal) for all LCLS quadrupole magnets and both solenoid magnets (S1 & S2). The sensitivities are the magnet displacement level which will alone generate a beam centroid offset (position and angle in the undulator) which is 10% of the nominal rms beam size.

Magnet Name	x sensitivity [μm]	y sensitivity [μm]	rms tolerance [μm]
S1	1.2	1.2	0.10
S2	2.615	2.850	0.50
QA01	2.615	2.850	0.10
QA02	1.864	3.338	0.10
QE01	25.023	21.28	0.50
QE02	12.427	9.899	0.50
QE03	2.493	4.259	0.10
QE04	3.918	4.203	0.10
QM01	1.615	1.652	0.10
QM02	6.088	1.007	0.10
QB	1.276	1.729	0.10
QM03	3.951	3.338	0.10
QM04	1.244	3.158	0.10
QA11	7.854	4.228	0.10
QA12	5.768	13.354	0.50
Q21201	1.793	1.499	0.10
QM11	1.505	3.040	0.10
CQ11	-	-	1
CQ12	-	-	1
QM12	2.834	0.998	0.10
QM13	1.599	1.665	0.10

⇩ 148 magnets

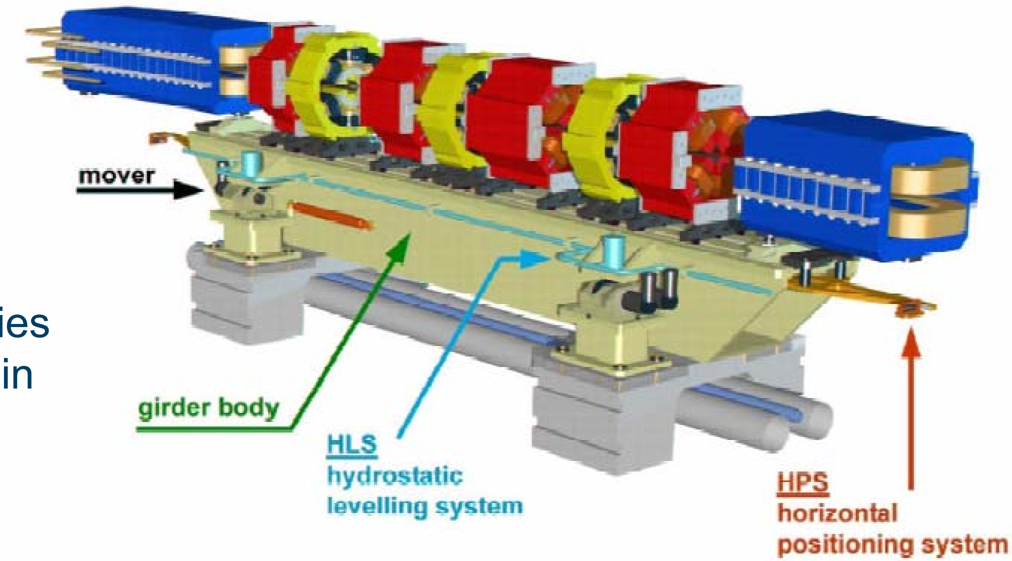
12 quads need rms vibration ≤500 nm

101 magnets need rms vibration ≤100 nm

35 quads need rms vibration ≤50 nm

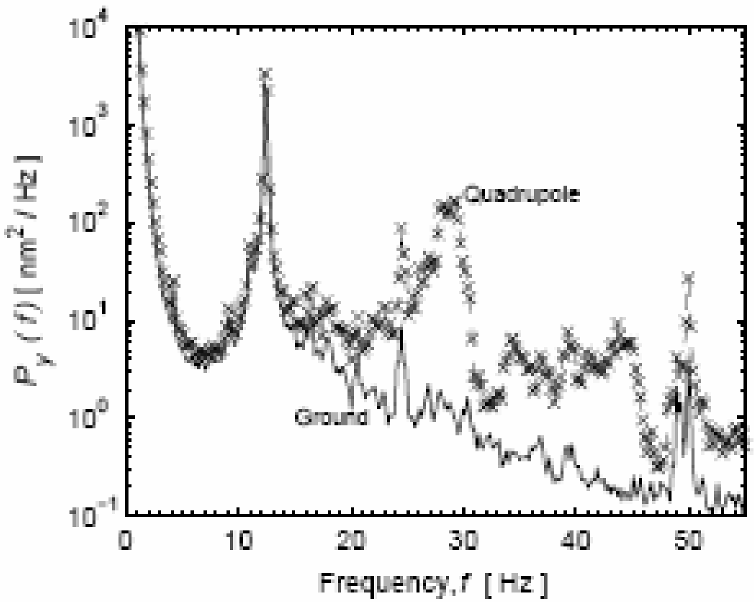
P. Emma, LCLS Week, July 28, 2005

SLS Girder System



" ..assessment on girder/magnet assemblies indicated that there are eigenfrequencies in this range [5-40Hz]. However, it was evidenced that the transmissibility of the girder/magnet assembly is ≤ 10 …"

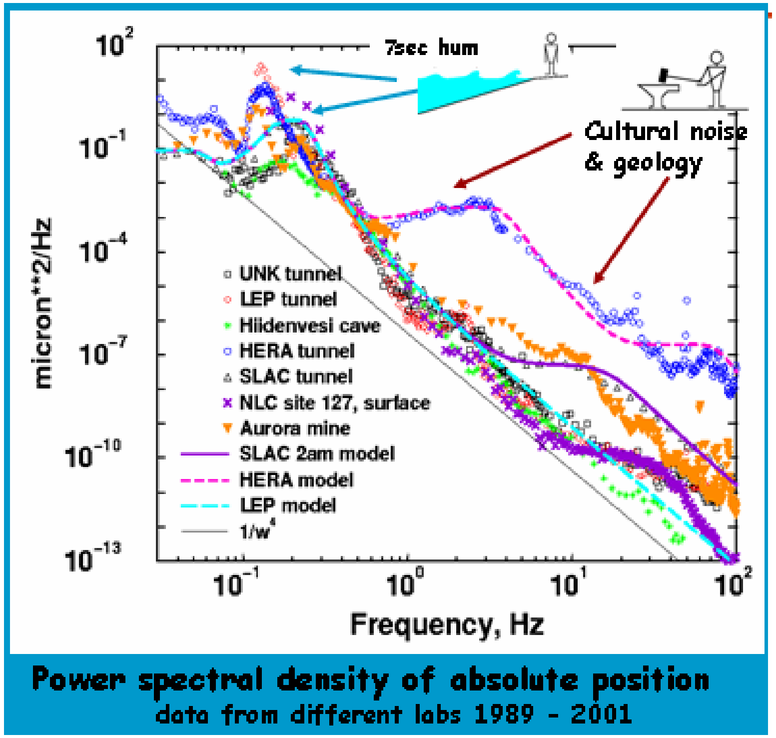
S. Zelenika et al. , NIM 2001



" Broad resonances are found at 28Hz-29Hz and in the 35Hz to 45 Hz range. They amplify the ground motion up to approximately 10 times."

S. Redaelli et al., EPAC 2004 THPK011

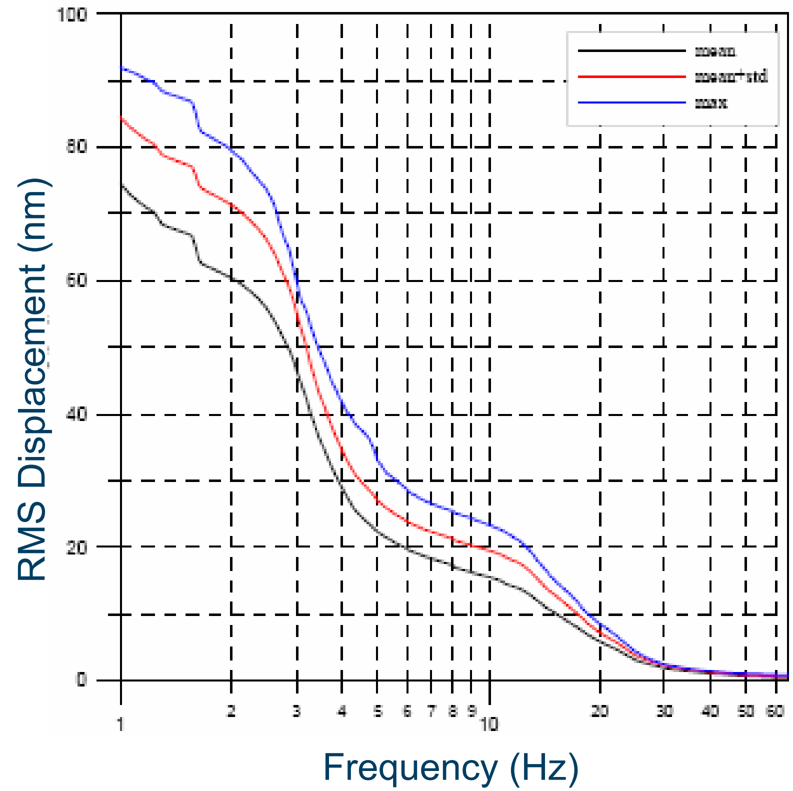
Ground Motion Characteristics



Seryi [2003]
http://www.desy.de/~njwalker/uspas/coursemat/pp/unit_8.ppt#10

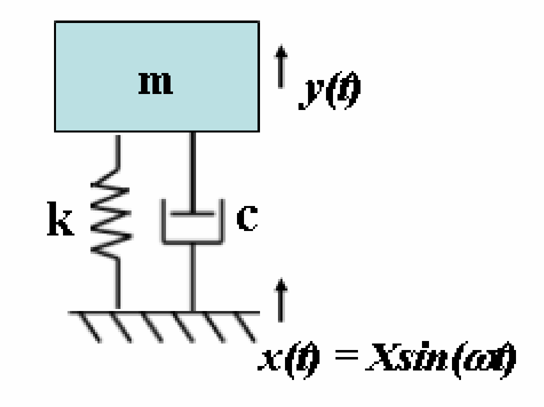
Ground Motion - NSRRC

D. J. Wang, NSRRC, 2005



- Ambient ground motion amplitude drops sharply at higher frequencies.
- A large fraction of the RMS ground motion is in the frequency band below 4 Hz. This motion may be highly correlated and may be corrected by the real time feedback control system. .

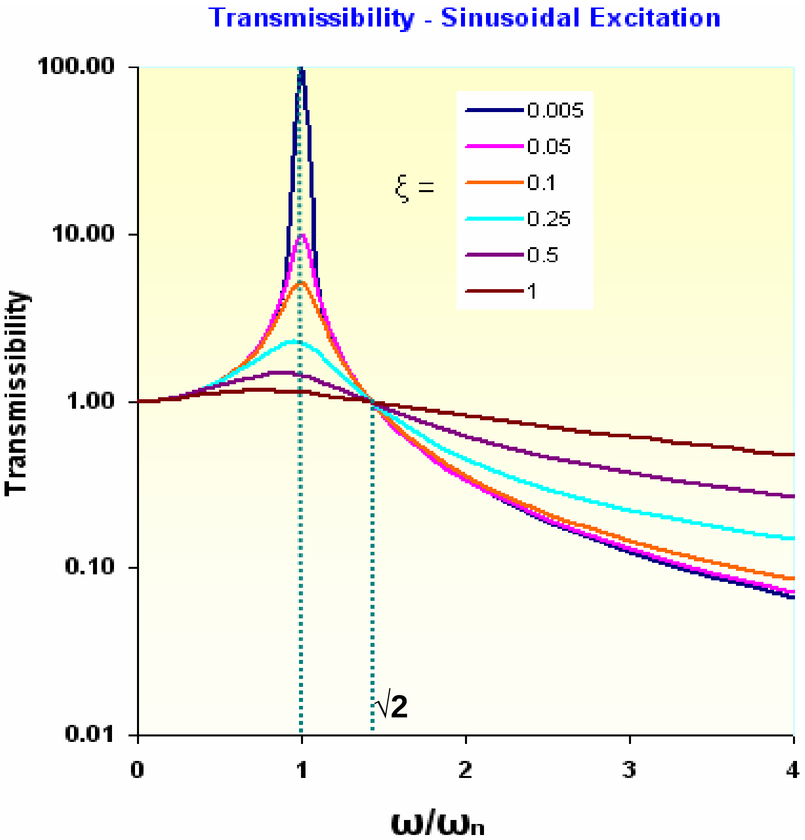
Transmissibility



$$\omega_n = \sqrt{k/m}$$

$$\xi = \frac{c}{2\sqrt{mk}} = \text{fraction of critical damping}$$

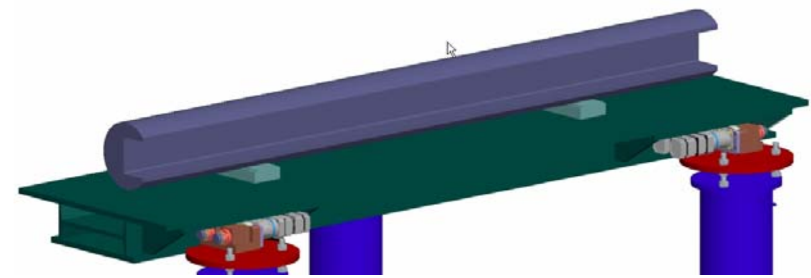
$$Transmissibility = \frac{Y}{X} = \sqrt{\frac{4\xi^2(\omega/\omega_n)^2+1}{[1-(\omega/\omega_n)^2]^2+4\xi^2(\omega/\omega_n)^2}}$$

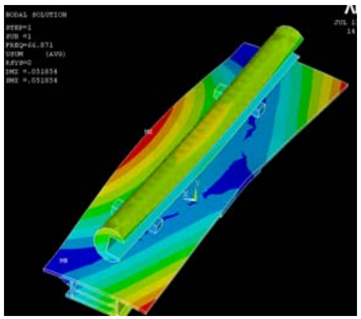


For vibration isolation:

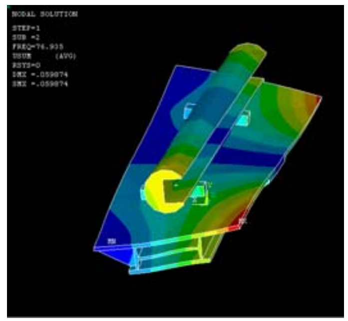
- Systems on soft supports ($\omega/\omega_n > \sqrt{2}$) → no damping.
- Systems on very stiff supports ($\omega/\omega1 << 1$) → damping is not necessary.
- Systems on intermediate-stiffness supports → damping is effective.

LCLS Girder System

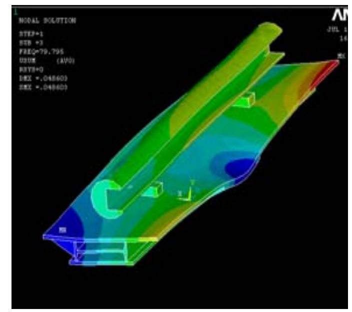




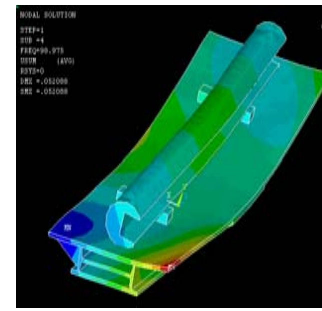
Mode-1 (67.9 Hz)



Mode-2 (76.9 Hz)

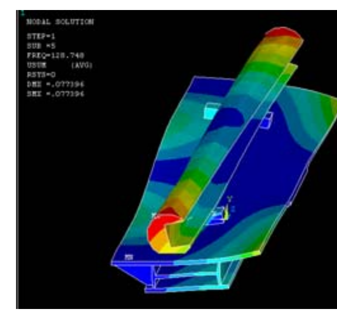


Mode-3 (79.8 Hz)



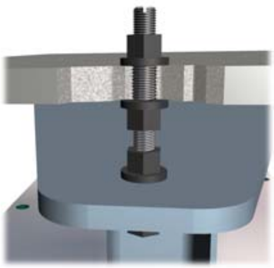
Mode-4 (99.0 Hz)

- The first four modes correspond to girder deformations (flexure, torsion, flexure, and flexure).
- Mode 5 corresponds to undulator torsion.

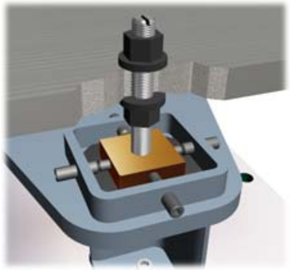


Mode-5 (128.8 Hz)

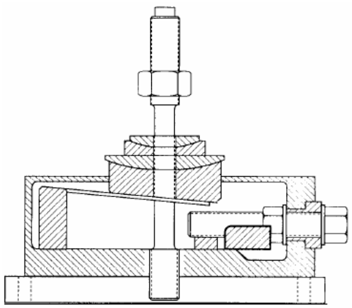
Alignment Mechanisms



Threaded Rod

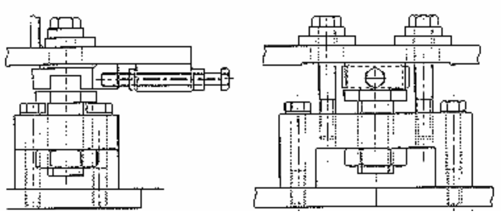


Threaded Rod with Lateral Adjustments (APS)



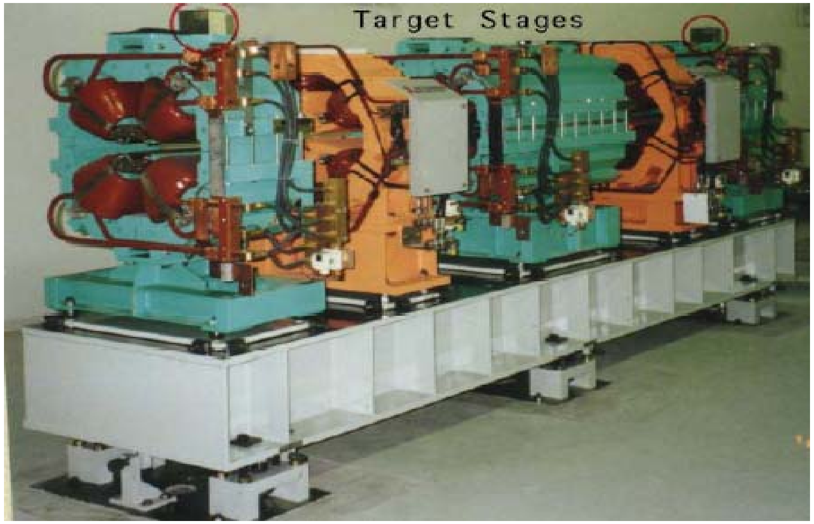
Wedge Jack (APS)

http://www-group.slac.stanford.edu/met/IWAA/TOC_S/PAPERS/KTsum02.pdf



SPring-8 Alignment

The alignment mechanism should be as stiff as possible – stability of the support system should be given a higher priority over ease-of-alignment.



Spring-8 Girder System

Summary

- The new design of the fixed support stand is nearly complete. The support stand will be thermally insulated and sand-filled.

- ΔT (air) of ± 0.5 ºC appears to be acceptable. The girder should be insulated to minimize thermal bending due to spatial temperature changes.

- Vibration tolerances (rms, 1-100Hz) may be too tight.